CAGCOM

A Program for Designing Dams for Gully Control

by

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CAGCOM

INTRODUCTION

Conventional field survey and design procedures for gully control with check dams require relatively large amounts of time and money. The proposed procedures, based on minimum field survey and computerized design of check dams, make feasible large-scale applications and inventory of treatment needs. Such inventories can be helpful in determining priorities in gully control, and show the overall requirements in funds and materials for watershed restoration with check dams. The low cost of obtaining this information makes it possible to inventory large land management units.

This updated report gives instructions for the use of CAGCOM on the Univac 1100/80, 1/ and presents the key equations of the program. Knowledge of these equations will enable the designer of gully treatments to judge the applicability of CAGCOM to his needs. For example, check dam designs used in the program may need to be modified for certain situations. If these modifications require different equations or coefficients, changes can easily be introduced. Thus, this paper provides greater flexibility in the use of CAGCOM, so that it can be applied in regions or countries where conditions differ from those of the southwestern United States.

The three primary topics of this report are: (1) key equations, (2) field and computer input procedures, and (3) sample problem.

1/ The computer is located at the Fort Collins Computer Center (FCCC), Fort Collins, Colo. Company names are used for the convenience of the reader and do not constitute endorsement or preferential treatment by the U.S. Department of Agriculture.

BACKGROUND

The user of the CAGCOM program will find the publication by Heede (1976, revised 1979) helpful for understanding historical and geomorphological aspects of gullies. Knowledge of gully formation and mechanics is prerequisite to the selection of gullies for control. This selection should also be based on the dynamic relationships between network gullies because, as shown by Heede (1978), not all gullies require treatment if physical structures and vegetation treatment are combined. Such an approach can lead to substantial cost savings.

Regardless of approach, watersheds should be regarded as dynamic systems. Individual parts of watersheds are not independent from each other because they interact.

Heede's (1976) paper should be used for developing construction plans, and as a guide for the actual construction. Examples of plans show the placement of keys, aprons, end sills, and other structural parts of the dam. Illustrations of finished dams show construction details such as steel reinforcements in bank protection work and in fence-type dams. The discussion of design criteria should also prove helpful.

A prior report (Heede and Mufich, 1973) contains a general description of the original computer program CAGCOM, and illustrates what this program can achieve in the design of gully control with check dams. Knowledge of functional relationships is important for deciding on type and number of check dams, predicting sediment deposits above dams, and estimating costs. The 1973 report can therefore be used with the updated CAGCOM program. The description and sample output are no longer valid, however, because they refer to the original program. Although the ALGOL program is replaced by a comparable FORTRAN program, the graphical output for the particular sample is valid.

KEY EQUATIONS

Four types of check dams and one head cut control structure, all built mainly from loose rock, are included in CAGCOM. Dam types are loose rock, wire-bound loose rock, single-fence, and double-fence dams. The head cut control structure consists of a wedge of loose rock placed against the head cut and sloped at 3:1 from the lip of the head cut to the gully bottom. Symbols used in the equations are illustrated in Appendix I. Appendix II shows schematic plots of check dams. Design for all structure types is available elsewhere (Heede, 1960 and 1966).

Rock Volumes

The calculations for volumes of loose rock and wire-bound loose rock dams were simplified by assuming a zero gully gradient. This assumption results in an underestimate of volumes in gullies with steep gradients. To offset this underestimate on gradients larger than 15 percent, the program adds 10 percent to the calculated volume.

Loose Rock and Wire-Bound Loose Rock Dams

The equation for loose-rock dams considers either of two types of rock, angular or round, because the angle of repose varies with rock shape and influences the side slopes of the dam. The generalized equation is

$$V_{LR} = \left(\frac{H}{\tan A_R} + 2\right) H \; L_A - V_{SP} \qquad (1)$$

where V_{LR} is the volume of the dam proper, H is dam height, 2 is the breadth of the core, L_A is the average length of the dam, tan A_R is the tangent of the angle of repose of the rock type, and V_{SP} is the volume of the spillway. It is assumed that the angle of repose for angular rock is represented by a slope of 1.25:1.00, corresponding to a tangent of 0.80.

For round rock, the slope is 1.50:1.00 with a tangent of 0.66. L_A is given by the equation

$$L_A = L_B + \frac{L_U - L_B}{2D} H \tag{2}$$

where L_B is the bottom width of the gully, L_U is the upper width of the gully, and D is the depth of the gully.

V_{SP} is calculated by the equation

$$V_{SP} = H_S \times L_{AS} \times B_A \tag{3}$$

where H_S is the depth and L_{AS} is the effective length of the spillway, and B_A is the breadth of the dam, measured at half the depth of the spillway and derived from the formula

$$B_A = \frac{H_S}{\tan A_R} + 2 \tag{4}$$

where 2 is the breadth of the dam at H.

From equation (1) it follows that less rock is required if angular shapes are used. Angular rock is also preferable because it makes a more stable dam than round rock.

If the design peak flow is larger than 10 ft^3/s (cubic feet per second), the dam must be designed for a 2- or 4-foot key, depending on soil type. For a 2-foot key, volumes of rock are computed by the equation

$$V_{K2} = (L_A + 4)\ (H + 2)\ (2) - L_A 2H \tag{5}$$

where (L_{A+4}) is the average length of dam plus two 2-foot keys, H+2 is the height of the dam plus the 2 foot bottom key, 2 is the breadth of the

key, and $L_A 2H$ is the volume of the dam core without keys. Similarly the volume of a 4-foot key is given by the equation

$$V_{K4} = (L_A + 8)\ (H + 2)(2) - L_A 2H \qquad (6)$$

with a key depth of 4 feet in each gully side slope and a 2-foot key depth in the gully bottom.

Field experience indicated that keys deeper than 4 feet would be required only in unusual cases, such as in soils with exceptionally high sand content. For more than 90 percent of all cases, key depths given by equations (5) or (6) should suffice. Where larger depths are required, the equation should be changed.

CAGCOM considers two groups of gully gradients for calculating rock volumes for apron and bank protection, each 1 foot thick. On gully gradients $\leq$ 15 percent, the length of apron is 1.50 times dam height, while on gradients > 15 percent, it is increased to 1.75 times dam height. The gully banks must be protected for the total length of the apron to prevent erosion by eddies. Loose rock is proposed as the main construction material. Its volume is calculated by the equation

$$V_A = cHL_B + 2cH^2 \qquad (7)$$

where V_A is the rock volume needed by the apron and both banks for protection, and c is a constant whose value depends on gully gradient. On gradients $\leq$ 15 percent, c = 1.50; on gradients > 15 percent, c = 1.75. Equation (7) is valid for all four dam types.

Single-Fence Dams

For calculating rock volume for single-fence dams, a zero gully gradient was assumed. This results in overestimates that compensate for

simplification of the equation for volume calculation. While the construction plan calls for a dam with a 2-foot breadth, for ease of calculation, the cross section of the dam parallel to the thalweg (the line joining the deepest points of a stream channel) is taken as a triangle with a dam side slope of 1.25:1.00. The equation is

$$V_{SF} = \frac{1}{2} \left(\frac{H}{\tan A_R} H \right) L_A - V_{SSF} \tag{8}$$

where V_{SF} is the rock volume of the dam proper, 2 is a constant, and tan A_R represents the tangent of a slope of 1.25:1.00. V_{SSF} is the volume of the spillway, calculated by the equation

$$V_{SSF} = H_S \times L_{AS} \times B_{SF} \tag{9}$$

where B_{SF} is the breadth of the dam, measured at half the depth of the spillway and given by the formula

$$B_{SF} = \frac{H_S}{2 \tan A_R} \tag{10}$$

Double-Fence Dams

The rock volume of a double-fence dam is expressed by the equation

$$V_{DF} = 2HL_A - V_{SDF} \tag{11}$$

where V_{DF} is the volume, 2 is the breadth of the dam, and V_{SDF} is the volume of the spillway, computed by the formula

$$V_{SDF} = H_S \times L_{AS} \times 2 \tag{12}$$

where 2 is the standard breadth of the dam.

Head Cut Control Structures

The volume requirements for a head cut control structure are given by the equation

$$V_{HC} = \left(\frac{3D^2}{2}\right)\left(\frac{L_U + 3L_B}{4}\right) \qquad (13)$$

where V_{HC} is the rock volume, D is the depth of the gully at the head cut, 3 is a coefficient that refers to a structure with a slope gradient of 3:1, and $\frac{L_U + 3L_B}{4}$ is the weighted average length of the structure.

Wire Mesh and Fence Posts

Bank Protection

Besides rock, wire mesh and steel fence posts are used in most of the dam types. If dam height is equal to or larger than 4 feet, CAGCOM provides automatically for reinforcement of the bank protection work by wire mesh and fence posts. The equation for square feet of wire mesh and number of posts includes a margin of safety to offset unforeseen additional needs. To assist in construction, the quantity of mesh is given in length and width. The length measured along the thalweg is

$$M_{LB} = 2(1.75H) \qquad (14)$$

where M_{LB} is the length of the wire mesh for the bank protection on both banks, and 1.75 is a constant. The width of the wire mesh equals total dam height.

The number of fence posts is calculated by the equation

$$N_B = 2\left[\left(\frac{1.75H}{4}\right) + 1\right] \qquad (15)$$

where N_B is the number of fence posts for the bank protection, rounded up to a whole even number, and 2 is for the two banks, 1.75H is the length of bank protection for gradients > 15 percent, 4 is for the 4-foot spacing of the posts, and 1 is for an end post. All posts are 2.5 feet taller than the dam. This equation applies a rule of thumb that 8, 10, or 12 posts will be required, depending on dam height (H) (since H is $\leq$ 7.5 feet). For most cases, these amounts include a surplus that should be used to offset losses, and/or for horizontal structural members in single- and double-fence dams. Horizontal members were not included in the post-number equations for these dam types.

Wire-Bound Dams

For wire-bound dams, the length of the wire mesh is taken as the length of the dam crest, which includes a safety margin and is calculated by the equation

$$M_L = L_B + \left(\frac{L_U - L_B}{D}\right) H \qquad (16)$$

where M_L is the length of the wire mesh. The width of the mesh, measured parallel to the thalweg, depends not only on dam height but also on rock shape. The equation for the width of the wire mesh is

$$M_W = 2\left(\frac{H}{\tan A_R} + \frac{H}{\sin A_R} + 2\right) + 6 \qquad (17)$$

where M_W is the width and A_R is the angle of repose of the rock. Equation (17) provides for an overlapping of the mesh by 6 feet. Only the dam proper will be encased in wire mesh.

Single-Fence Dams

For a single-fence dam, the length of wire mesh is given by equation (16), and the width of the wire mesh is equal to dam height. The number of

fence posts is calculated by the equation

$$N_{SF} = \frac{1}{4}\left[L_B + \left(\frac{L_U - L_B}{D}\right)H\right] + 1 \qquad (18)$$

where N_{SF} is the number of posts for the dam proper of a single-fence dam, rounded up to a whole number, 4 signifies a distance of 4 feet between the posts, and 1 is for an end post. Of the total number of posts, half are 2.5 feet taller than the dam, the other half are dam height.

Double-Fence Dams

For double-fence dams, the length of wire mesh is given by

$$M_{LD} = 2\left(L_B + \frac{L_U - L_B}{D} H\right) \qquad (19)$$

where M_{LD} is the length of the mesh. The width of the wire mesh equals dam height. The number of fence posts is computed by the equation

$$N_{DF} = 2\left(\frac{1}{4}\left[L_B + \left(\frac{L_U - L_B}{D}\right)H\right] + 1\right) \qquad (20)$$

where N_{DF} is the number of posts of the dam proper of a double-fence dam, rounded up to a whole even number. One half of the number of posts are dam height, while the other half are 2.5 feet taller than the dam.

Spillway Design

Most gullies are either trapezoidal, rectangular, or V-shaped in cross section. CAGCOM differentiates between these shapes. For ease of design, it was assumed that V-shaped gullies have a bottom width of 4 feet or less, and/or this width has a dimensionless value equal to 0.075Q or less, where Q is the design peak flow. It was found empirically that spillways can be fitted more easily into V-shaped gullies, if bottom width--peak flow relations were also considered. The coefficient 0.075 proved to be satisfactory to express this relationship.

Rectangular gullies have a bottom width larger than 4 feet, and the difference between bank and bottom widths is less than 2 feet. In trapezoidal gullies, bottom width is larger than 4 feet and the difference between bank and bottom widths is 2 feet or more.

<u>V-Shaped and Rectangular Gullies</u>

In V-shaped and rectangular gullies, the equation for the depth of the spillway is

$$H_{SV} = \left(\frac{Q}{CL_{AS}}\right)^{2/3} \tag{21}$$

Equation (21) is derived from the formula for a broad-crested weir, where H_{SV} is the depth of the spillway which for our dams cannot be smaller than 1.0 foot. C is the discharge coefficient, which for reasons of practicality is taken as 3.0. L_{AS}, the effective length of spillway, is computed by the equation

$$L_{AS} = \frac{L_U}{D} H_E - f \tag{22}$$

where f is a constant, referring to the length of the freeboard and having a value of 1 in gullies with a depth of 5 feet or less, and a value of 2 in gullies with depths larger than 5 feet. The designer either specifies the effective dam height (H_E), or the program uses the maximum possible effective height (H_{Ea}). In the second case, in equation (22), H_E is replaced by H_{Ea} which is derived from the equation

$$H_{Ea} = D - g \tag{23}$$

where the value of g is 1.0 foot in gullies with depths of 5 feet or less, and 1.5 feet in gullies with depths larger than 5 feet but not larger than

8 feet. The value of g corresponds to a depth of spillway of 1 foot in a dam whose total height equals depth of gully. The value 1.5 means that, in gullies with depths between 5 and 8 feet, the total dam height equals the gully depth minus 0.5 foot, and the depth of spillway is 1 foot. If gully depth is larger than 8 feet, D is taken as 8 feet and g is 1.5 feet.

Spillways are designed with a side slope of 1:1. Equation (22) includes a safety margin, because the effective length of the spillway is calculated with reference to the width of the gully at the elevation of the spillway bottom, instead of that at half the depth of the spillway. At spillway bottom elevation, gullies are generally narrower than at the location of the effective spillway length. This results in somewhat smaller spillway lengths, which will benefit the fit of the spillway into the dam and the gully.

Since the spillway sides are sloped 1:1, it follows that, in V-shaped and rectangular gullies, the bottom length of the spillway (L_{BSV}) is derived from the equation

$$L_{BSV} = L_{AS} - H_{SV} \tag{24}$$

and the length between the brinks of the spillway (L_{USV}) is given by the equation

$$L_{USV} = L_{AS} + H_{SV} \tag{25}$$

With the exception of Q and C, all units in equations (21) to (25) are in feet. While Q is in cubic feet per second, C is a dimensionless constant.

Throughout the program, the calculated dimensions of spillway and dam are tested to be sure they fit the gully and comply with the design

specifications. Specifications for spillways are: minimum bottom length and minimum depth, 1 foot; for freeboards, minimum length at each end of the dam is 0.5 foot and 1.0 foot for gullies 5 feet deep or less and those deeper than 5 feet, respectively. Through an iterative process, the program will attempt to attain the fit by adjusting effective length and depth of spillway, which in turn can lead to adjustments in effective and total dam heights. During the adjustment of the spillway dimensions, the spillway side slopes are maintained at 1:1, unless the bottom width of the spillway is less than 1 foot. In this case, the side slopes will be steepened beyond 45°. This design deviation will not be critical where small flows are involved or insignificant amounts of debris are expected in the flows. If the deviation is critical, the design should not be used and control measures other than check dams may be required. If fit cannot be attained, either very small gully dimensions or overestimates of peak flows are responsible, generally. The program will not yield a design, but a message stating the lack of fit.

Trapezoidal Gullies

In trapezoidal gullies, the effective length of the spillway equals the bottom width of the gully. From the discharge formula for broadcrested weirs, it follows that the depth of spillway (H_S) in these gullies is given by the equation

$$H_S = \left(\frac{Q}{CL_B}\right)^{2/3} \tag{26}$$

Lengths at the bottom (L_{BS}) and between the brinks of the spillway (L_{US}) are calculated by the equations

$$L_{BS} = L_B - H_S \tag{27}$$

and

$$L_{US} = L_B + H_S \tag{28}$$

respectively. All units in equation (26) to (28) are in feet, except Q and C, which are in cubic feet per second and dimensionless, respectively.

If a specific value for effective dam height is requested, total dam height is calculated by adding the depth of spillway to effective dam height. If a specific effective height is not requested, the program yields the maximum possible effective height by subtracting depth of spillway from the maximum possible dam height. As in V-shaped and rectangular gullies, adjustments are made to avoid dams larger than gully depth or higher than 7.5 feet, and to assure compliance with the other design criteria.

FIELD AND COMPUTER INPUT PROCEDURES

Phase I: General Dam Network Design

The design procedures comprise two phases. In Phase I, sample field, photo, and map data and other basic design information are input to CAGCOM to obtain a general dam network design. In Phase II, site-specific field data are input to CAGCOM to obtain a design for each individual dam. In Phase I, a field survey determines the representative cross section of the gully or gully section, the gradient of the gully or section, the type of soil, and the size of the watershed. Cross sectional dimensions are bottom and bank width, and depth of gully.

Obviously, the quality of the selection of the representative cross section will influence the quality of the output of Phase I and hence its closeness to the final results of Phase II. To improve the quality, it may be advantageous to divide the gully into two or three sections. Most gullies vary along their course with some degree of consistency. For example, they become wider toward gully mouth, are steeper in the headwater section, medium steep in the middle section, and relatively flat in the downstream section. The selection of representative gully cross sections should not be based on random procedures but must be biased. The bias should reflect the best judgment of the typical dimensions of the gully that will be treated as one unit in Phase I. Normally, only a few selected cross sections must be surveyed in each gully to obtain meaningful values.

Length of gully or sections and size of watershed area can be taken from aerial photos or maps of appropriate quality. Although size of watershed area and other watershed characteristics such as topography and vegetation cover are not input data for the program, they must be appraised

for the calculation of Q, the expected peak flow of the design storm. A computer program, such as the TR-20 program developed by SCS, is available to facilitate this calculation.

In addition to the above data, the input for Phase I must include design information for the structural key, the shape of the construction rock, the base cost, and the unit value of sediment. If the expected peak flow is larger than 10 ft^3/s the depth of the key must be specified, based on type of soil. Research has shown that rock check dams do not require keys if expected peak flows are smaller than 10 ft^3/s (Heede 1960). A survey of available rock should ascertain if round or angular rock will be used. The base cost, the cost of placing one cubic yard of rock into a dam, should be derived from local projects if possible. This cost can refer to any dam type, but for wire-bound or fence-types it should include the cost of the wire mesh and fence posts that reinforce one cubic yard of the structure. Great care should be exercised in establishing the base cost figures, because costs for other types may be derived from empirical indices as follows:

Type of dam	Cost index
Loose-rock	1.00
Wire-bound loose rock	1.07
Single-fence	1.28
Double-fence	1.47

If available, the value (removal cost) of one cubic yard of sediment should be taken from local projects such as cleaning or construction of stock ponds and fish ponds, or dredging of reservoirs. Otherwise, average regional costs must be used.

In summary, the input into the program of Phase I includes the following items:

- Gully no.
- Section no.
- Length
- Bank width
- Bottom width
- Depth
- Gradient
- Effective dam height; if not specified, use value of gully depth
- Peak flow
- Key or no key
- Depth of key
- Rock shape
- Base cost in dollars of one cubic yard of dam
- Unit value of one cubic yard of sediment

The output of part 1 of Phase I contains information as follows:

- Spacing of dams, based on specified effective dam height or maximum possible effective height
- Number of dams required
- Effective dam height
- Total dam height
- Spillway dimensions
- Rock volumes required in each type of dam
- Wire mesh and fencepost requirements for each dam type, and, if applicable, also for bank protection

- Total rock volumes required, by each of the four dam types
- Rock volumes for headcut control structures where applicable
- Total volume of expected sediment deposits
- Total requirements of wire mesh and fenceposts by number of wire rolls, and number and length of posts for each type of treatment
- Cost of each type of dam and headcut control structure, if applicable
- Total cost of treatment by each type of dam
- Total value in dollars of sediment deposits
- Table on spacing-height relationships

Part 2 of Phase I produces a plot of cost per treatment vs. effective dam height for any combination of dam types and sediment value, and is optional. This part may be omitted if the designer has already decided on the type of dam and the effective dam height. For example, in cases where loose rock is available in large quantities and gully depth is only a few feet, conditions strongly favor the installation of loose rock dams with maximum possible effective height.

If part 2 is retained, the graph generated is the main basis for the final selection of type and effective height of dam. The principal criterion for selection may be either the lowest cost treatment, the largest amount of sediment deposits, the smallest volume requirements for rock, the highest sediment-cost ratio, the smallest number of dam sites, or any combination of these and other criteria.

If a new effective dam height was not selected, the spacing given in part 1 will be retained for the final design. If an effective dam height is selected that was not generated in Phase I, the table on spacing-height

relationships, appended to the tabular output of Phase I, should be consulted to determine the spacing. An example of input for Phase I is given in Appendix III.

Phase II: Individual Dam Designs

Dam spacing forms the basis for field surveys in Phase II. At each proposed dam site, the crew surveys the gully cross section as in Phase I, but the advantages and disadvantages of the site for the installation of a dam must be considered. Advantages include the occurrence of bedrock, if fence-type dams will not be installed; ease of access; and cross sections that require small dams. Some disadvantages are locations with exceptionally large cross sections, but small cross sections above the dam sites; inherent tendencies for bank sloughing; springs and excessive bank seepage. If a proposed site does not appear to be favorable for dam installation, the survey crew should select a more favorable location nearby wherever possible. All locations must be identified on the ground for subsequent installation.

The data for the individual dam sites, obtained in survey Phase II, replace the input on representative widths and depth of Phase I, and together with the unreplaced data, form the input of Phase II. While Phase I generated one prototype design for all dam types and sites, Phase II yields individual designs for each dam. Requirement totals for materials and funds as well as sediment benefits are based on the individual designs. Effective dam height and dam type can be specified for each dam, or one given height and type may be chosen for all. In all cases, heights and spillway dimensions are adjusted to fit the site and not violate design criteria such as minimum length of freeboard or maximum permissible height of dam.

If the effective height of a dam generated in Phase II is less than or equal to half of that used in Phase I, an additional dam will be designed for installation at the upstream toe of the expected sediment wedge. With the exception of height, the dam size will be calculated, based on the average of the cross sectional dimensions of the next upstream and downstream dam sites. An effective height will be selected that, if possible, allows the future deposits to reach the next upstream dam. If this objective cannot be achieved, the designer may perform Phase II again, using different effective heights and structural spacing. The output of Phase II lists the distance between the lower and additional dam as well as the upstream extent of the sediment deposits expected above the additional dam. If the sum of these two distances is less than the dam spacing of Phase I, deposits of the additional dam are not expected to reach the next upstream dam.

If the effective height of dam in Phase II is smaller than that of Phase I but larger than half its value, no additional dam will be designed. If a knickpoint should develop at the upstream toe of the sediment deposits on the gully bottom, a small dam should be installed during project maintenance work. An example of input for Phase II is given in Appendix IV.

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Appendix I

Symbols

A_R the angle of repose of rock

B_A the breadth of loose rock or wire-bound loose rock dams, measured at one half of the depth of spillway

B_{SF} the breadth of single-fence dams, measured at one half of the depth of spillway

C the discharge coefficient, taken as 3.0

c a constant referring to the gully gradient

D the depth of a gully

f a constant referring to the length of the freeboard whose value depends on gully depth

g a constant referring to the relation of spillway height, gully depth, and dam height

H the total height of dam

H_E the effective height of dam, the elevation of the crest of the spillway above the original gully bottom

H_{Ea} the possible maximum effective dam height

H_S the depth of spillway of a dam installed in a rectangular or trapezoidal gully

H_{SV} the depth of spillway for a dam installed in a V-shaped gully

L_A the average length of dam

L_{AS} the effective length of spillway

L_B the bottom length of the gully

L_{BS} the bottom length of the spillway of a dam installed in a rectangular or trapezoidal gully

L_{BSV} the bottom length of the spillway of a dam installed in a V-shaped gully

L_U the width of the gully between the gully brinks

L_{US} the length between the brinks of the spillway of a dam installed in a rectangular or trapezoidal gully

L_{USV} the length between the brinks of the spillway of a dam installed in a V-shaped gully

M_L the length of the wire mesh of a wire-bound dam

M_{LB} the length of the wire mesh of the bank protection, measured parellel to the thalweg

M_{LD} the length of the wire mesh for a double-fence dam

M_W the width of the wire mesh of a wire-bound dam, measured parallel to the thalweg

N_B the number of fence posts of the bank protection work

N_{DF} the number of fence posts of the dam proper of a double-fence dam

N_{SF} the number of fence posts of the dam proper of a single-fence dam

Q the rate of the peak flow in ft^3/s, based on the design storm

V_A the volume of the apron and bank protection

V_{HC} the volume of a headcut control structure

V_{DF} the volume of the dam proper of a double-fence dam

V_{K2} the volume of the key, 2 feet deep

V_{K4} the volume of the key, 4 feet deep

V_{LR} the volume of the dam proper of a loose rock dam

V_{SF} the volume of the dam proper of a single-fence dam

V_{SP} the volume of the spillway of loose rock and wire-bound loose rock dams

V_{SDF} the volume of the spillway of a double-fence dam

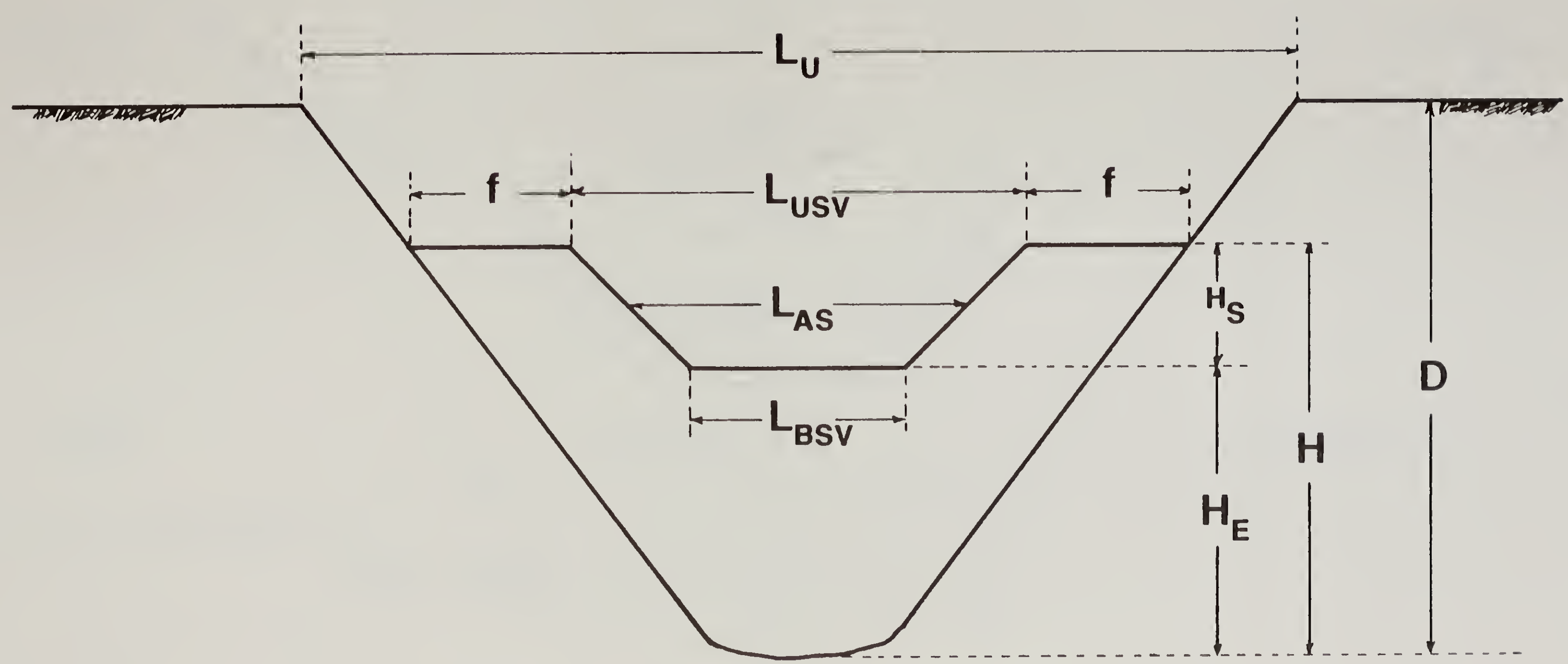
V_{SSF} the volume of the spillway of a single-fence dam

Appendix II

General Figures

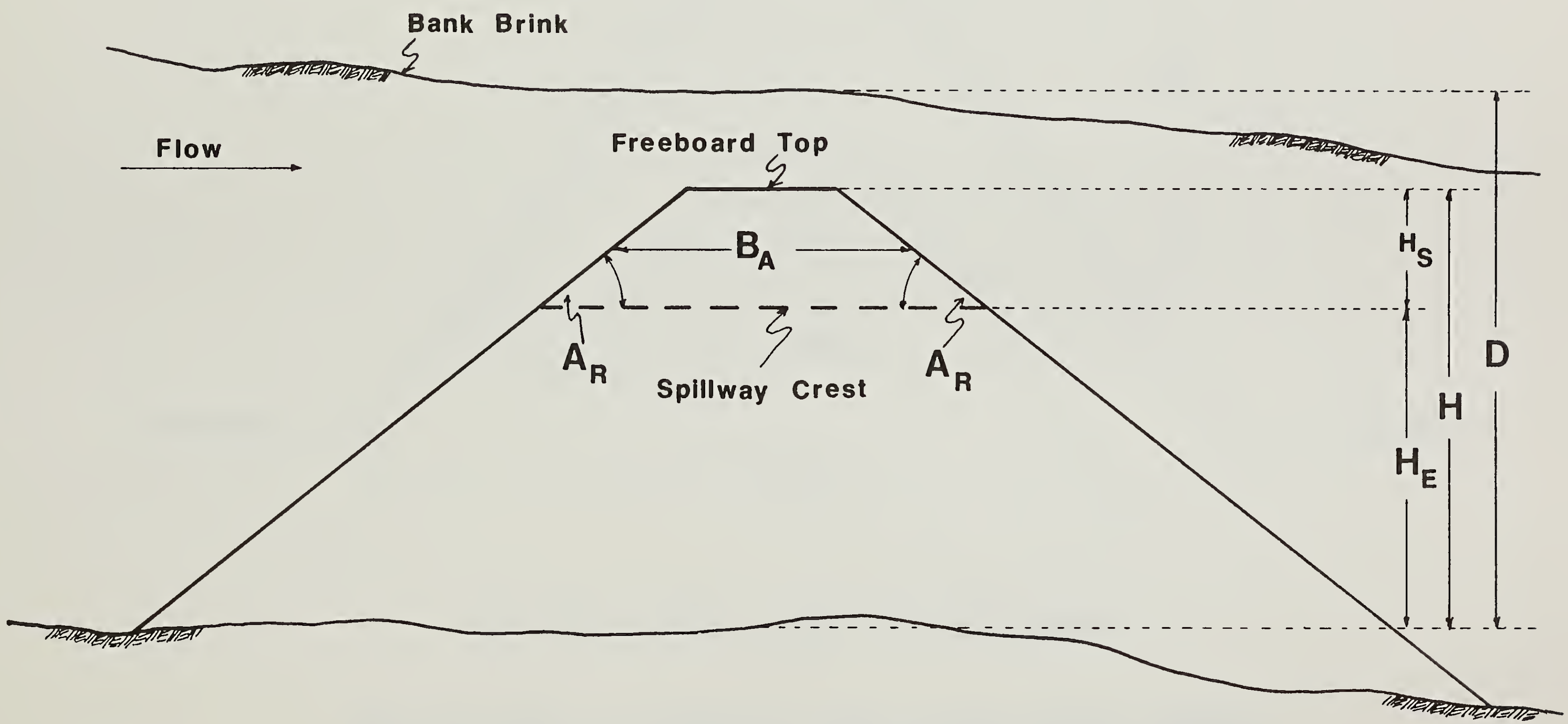
Check Dam in V-Shaped and Rectangular Gullies

Section Right Angle to Waterflow



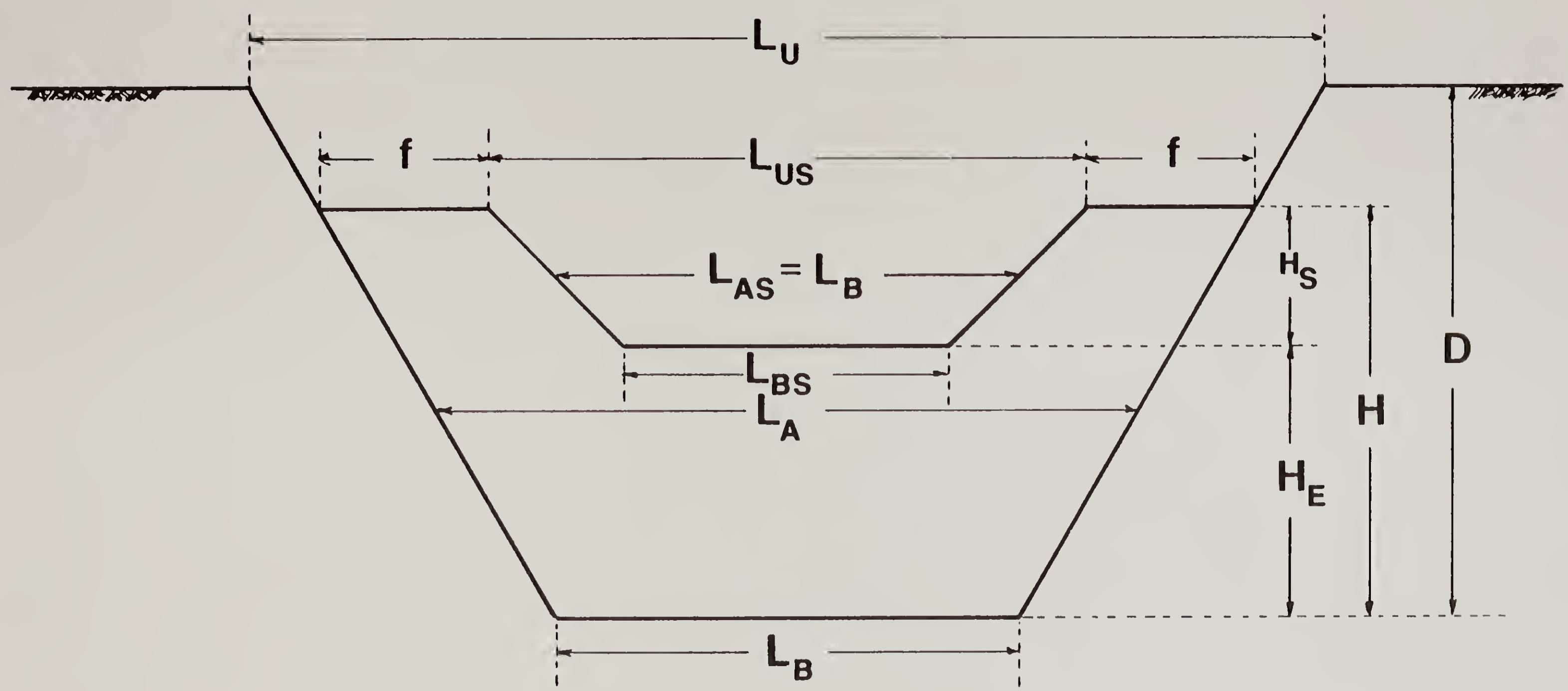
Loose Rock and Wire-Bound Loose Rock Dam

Section Parallel to Waterflow



Check Dam in Trapezoidal Gully

Section Right Angle to Waterflow



Appendix III

Phase I

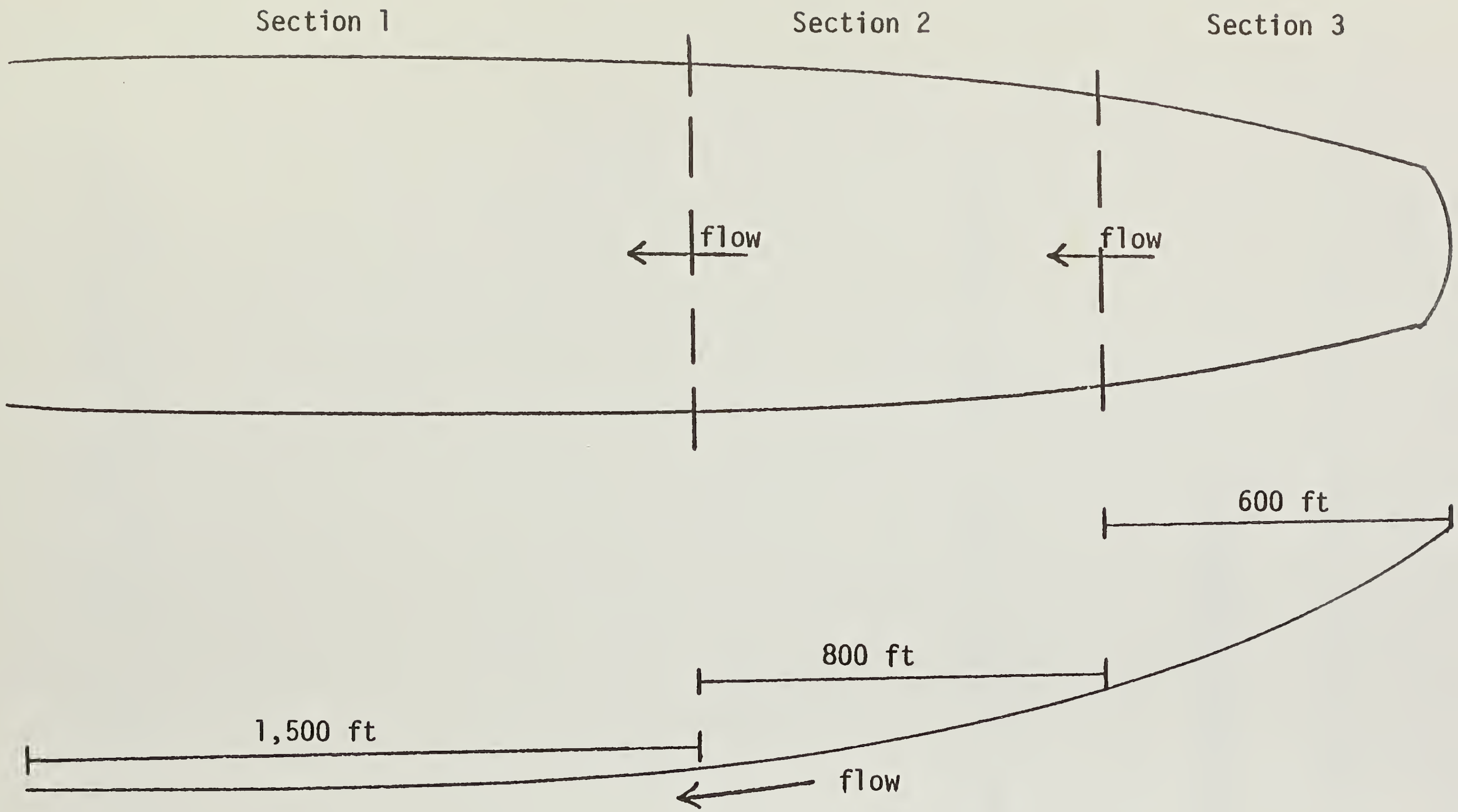
The following is an example of the required input and the resulting output for the execution of Phase I of the CAGCOM program. 1/ Refer to the accompanying figures for gully specifications and dimensions of the chosen representative sites. Cost of the rock and value of the sediment were taken as $30.00 per cubic yard and $5.00 per cubic yard, respectively.

Example of Input for Phase I 2/

```
WSDU*SAM(1).CAGCOM-1
1
HYPOTHETICAL RESTORATION PROJECT:  PHASE 1 - DESIGN ALTERNATIVES
1,30,5.00
1,1,3
1
1,1,1,1,1
2,100,4,0,0
1500,20,15,5,4
1,2,3
1
1,1,1,1,1
4,75,2,1,0
800,15,10,6,5
1,3,3
1
1,1,1,1,1
6,50,2,1,1
600,10,5,6,5
0,0,0
```

1/ The example was developed by John P. Potyondy, Hydrologist, Region 4.

2/ For explicit execution instructions, refer to WSDG's USERGUIDE program.



Representative site for Section 1

Gully top = 20 ft
Gully bottom = 15 ft
Gully depth = 5 ft
Effective height = 4 ft
Peak flow = 100 ft^3/s
Key = 4 ft
Rock type = round
No headcut present
Gully gradient = 2%

Representative site for Section 2

Gully top = 15 ft
Gully bottom = 10 ft
Gully depth = 6 ft
Effective height = 5 ft
Peak flow = 75 ft^3/s
Key = 2 ft
Rock type = angular
No headcut present
Gully gradient = 4%

Representative site for Section 3

Gully top = 10 ft
Gully bottom = 5 ft
Gully depth = 6 ft
Effective height = 6 ft
Peak flow = 50 ft^3/s
Key = 2 ft
Rock type = angular
Headcut present
Gully gradient = 6%

Gully specifications for example problem--Phase 1.

```
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789(12345



@ASG,A WSDU*WATER.
FACILITY WARNING  000200000000


@ASG,A WSDU*SAM.
FACILITY WARNING  000200000000


@ASG,T 7.,F///300
READY


@XQT WSDU*WATER.CAGCOM
   ENTER 1 TO RUN PHASE1 OR 2 TO RUN PHASE2



@ADD,P WSDU*SAM.CAGCOM-1

 ENTER 72 CHARACTERS OF IDENTIFYING INFORMATION FOR THIS RUN

 ENTER DAM TYPE, DAM'S BASE COST, UNIT VALUE OF SEDIMENT
 USE THE FOLLOWING NUMERIC CODES TO ENTER DAM TYPE.
      1 = LOOSE ROCK (LR)
      2 = WIREBOUND LOOSE ROCK (WB)
      3 = SINGLE FENCE (SF)
      4 = DOUBLE FENCE (DF)


 ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS


 ENTER PLOT ENABLE CODE
            0 - NO PLOT DESIRED
            1 - PLOT DESIRED

 ENTER 5 CURVE PLOT CODES IN THIS ORDER
            LOOSE ROCK DAM
            WIREBOUND LOOSE ROCK DAM
            SINGLE FENCE DAM
            DOUBLE FENCE DAM
            SEDIMENT VALUE

            0-NO PLOT DESIRED
            1 - PLOT DESIRED

 ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
```

```
DATE IS 051381     PHASE1
HYPOTHETICAL RESTORATION PROJECT:  PHASE 1 - DESIGN ALTERNATIVES


GULLY =     1
REACH =     1  OF     3
GRADIENT   =     2.00 %
PEAK FLOW   =  100.00 CFS


KEYS ARE 4 FT
ROCKS ARE ROUND
HEADCUT NO
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
ENTER LENGTH OF REACH,TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT


SINCE GULLY DEPTH IS BETWEEN 2.5 AND 5, ALTERNATE SPILLWAY CALCULATION USED.


SPACING=  534.71 FT      DAM HEIGHT =     5.00 FT
NO. OF DAMS =     2.81      NDAMS =     3

DAM DIMENSIONS
     DAM HEIGHT                      =     5.00 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                 =     3.21 FT
     TOP LENGTH OF SPILLWAY          =    15.59 FT
     EFFECTIVE LENGTH OF SPILLWAY =    13.89 FT
     BOTTOM LENGTH OF SPILLWAY       =    12.19 FT
     DEPTH OF SPILLWAY               =     1.79 FT

MATERIALS AND COSTS          LOOSE ROCK DAM
     ROCK VOLUME =   40.38 CU YD     COST = $ 1211.27

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   17.50 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =   87.50 SQ FT
       10 POSTS AT     7.5 FT LENGTH EACH

MATERIALS AND COSTS          WIREBOUND LOOSE ROCK DAM
     ROCK VOLUME =   40.38 CU YD     COST = $ 1296.06
     WIRE FOR DAM
     LENGTH OF MESH  =   20.00 FT
     WIDTH OF MESH  =   43.18 FT
     TOTAL MESH     =  863.68 SQ FT

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   17.50 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =   87.50 SQ FT
```

```
   10 POSTS AT      7.5 FT LENGTH EACH

MATERIALS AND COSTS          SINGLE FENCE DAM
     ROCK VOLUME =   24.71 CU YD     COST = $  948.94

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   20.00 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =  100.00 SQ FT
        3 POSTS AT      7.5 FT LENGTH EACH
        3 POSTS AT      5.0 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   17.50 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =   87.50 SQ FT
       10 POSTS AT      7.5 FT LENGTH EACH

MATERIALS AND COSTS          DOUBLE FENCE DAM
     ROCK VOLUME =   18.32 CU YD     COST = $  808.02

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   40.00 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =  200.00 SQ FT
        6 POSTS AT      7.5 FT LENGTH EACH
        6 POSTS AT      5.0 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   17.50 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =   87.50 SQ FT
       10 POSTS AT      7.5 FT LENGTH EACH
```

TOTAL ROCK VOLUME FOR 3 DAMS,ONE HEADCUT CONTROL, AND TOTAL SEDIMENT CATCH IN CU YD.

LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
121.13	121.13	74.14	54.97	.00	1581.81

WIRE MESH AND POSTS PER TREATMENT (1 ROLL=2.7FT BY 330FT)

TYPE OF DAM	WIRE MESH AREA SQ FT	WIRE MESH NUMBER OF ROLLS	NUMBER POSTS AT 7.50 FT	NUMBER POSTS AT 5.00 FT
LOOSE ROCK DAM	262.50	.3	30	0
WIREBOUND LOOSE ROCK DAM	2853.53	3.2	30	0
SINGLE FENCE DAM	562.50	.6	39	9
DOUBLE FENCE DAM	862.50	1.0	48	18

$COST OF DAMS,$COST OF PROTOTYPE HEADCUT CONTROL AND $VALUE OF SEDIMENT

	LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
PER CU YD	30.00	32.10	38.40	44.10		

```
PER DAM          1211.27     1296.06      948.94      808.02          .00      2636.35
  3 DAMS         3633.82     3888.19     2846.81     2424.05                   7909.05


TABLE OF SPACING VS SPILLWAY  HEIGHT
     SPLWY HGHT     SPACING

         1.0          166.70
         1.5          250.05
         2.0          333.40
         2.5          416.75
         3.0          500.10
         3.5          583.45

ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS


ENTER PLOT ENABLE CODE
          0 - NO PLOT DESIRED
          1 - PLOT DESIRED

ENTER 5 CURVE PLOT CODES IN THIS ORDER
          LOOSE ROCK DAM
          WIREBOUND LOOSE ROCK DAM
          SINGLE FENCE DAM
          DOUBLE FENCE DAM
          SEDIMENT VALUE

          0-NO PLOT DESIRED
          1 - PLOT DESIRED

ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
```

```
DATE IS 051381     PHASE1
HYPOTHETICAL RESTORATION PROJECT:  PHASE 1 - DESIGN ALTERNATIVES


GULLY =     1
REACH =     2  OF      3
GRADIENT    =     4.00 %
PEAK FLOW    =    75.00 CFS


KEYS ARE 2 FT
ROCKS ARE ANGLR
HEADCUT NO
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
ENTER LENGTH OF REACH,TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT


SPACING=  293.74 FT      DAM HEIGHT =     5.50 FT
NO. OF DAMS =     2.72      NDAMS =     3

DAM DIMENSIONS
     DAM HEIGHT                       =     5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                  =     3.52 FT
     TOP LENGTH OF SPILLWAY           =    10.83 FT
     EFFECTIVE LENGTH OF SPILLWAY =     8.99 FT
     BOTTOM LENGTH OF SPILLWAY        =     7.14 FT
     DEPTH OF SPILLWAY                =     1.98 FT

MATERIALS AND COSTS           LOOSE ROCK DAM
     ROCK VOLUME =    29.73 CU YD     COST = $  892.00

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =    19.25 FT
     WIDTH OF MESH  =     5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH

MATERIALS AND COSTS           WIREBOUND LOOSE ROCK DAM
     ROCK VOLUME =    29.73 CU YD     COST = $  954.44
     WIRE FOR DAM
     LENGTH OF MESH  =    14.58 FT
     WIDTH OF MESH  =   41.36 FT
     TOTAL MESH     =  603.10 SQ FT

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =    19.25 FT
     WIDTH OF MESH  =     5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH

MATERIALS AND COSTS           SINGLE FENCE DAM
```

ROCK VOLUME = 18.25 CU YD COST = $ 700.84

WIRE AND POSTS FOR DAM
LENGTH OF MESH = 14.58 FT
WIDTH OF MESH = 5.50 FT
TOTAL MESH = 80.21 SQ FT
3 POSTS AT 8.0 FT LENGTH EACH
3 POSTS AT 5.5 FT LENGTH EACH

WIRE AND POSTS FOR BANK PROTECTION
LENGTH OF MESH = 19.25 FT
WIDTH OF MESH = 5.50 FT
TOTAL MESH = 105.87 SQ FT
10 POSTS AT 8.0 FT LENGTH EACH

MATERIALS AND COSTS DOUBLE FENCE DAM
ROCK VOLUME = 14.15 CU YD COST = $ 624.05

WIRE AND POSTS FOR DAM
LENGTH OF MESH = 29.17 FT
WIDTH OF MESH = 5.50 FT
TOTAL MESH = 160.42 SQ FT
5 POSTS AT 8.0 FT LENGTH EACH
5 POSTS AT 5.5 FT LENGTH EACH

WIRE AND POSTS FOR BANK PROTECTION
LENGTH OF MESH = 19.25 FT
WIDTH OF MESH = 5.50 FT
TOTAL MESH = 105.87 SQ FT
10 POSTS AT 8.0 FT LENGTH EACH

TOTAL ROCK VOLUME FOR 3 DAMS, ONE HEADCUT CONTROL, AND TOTAL SEDIMENT CATCH IN CU YD.

LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
89.20	89.20	54.75	42.45	.00	658.57

WIRE MESH AND POSTS PER TREATMENT (1 ROLL=2.7FT BY 330FT)

TYPE OF DAM	WIRE MESH AREA SQ FT	WIRE MESH NUMBER OF ROLLS	NUMBER POSTS AT 8.00 FT	NUMBER POSTS AT 5.50 FT
LOOSE ROCK DAM	317.62	.4	30	0
WIREBOUND LOOSE ROCK DAM	2126.92	2.4	30	0
SINGLE FENCE DAM	558.25	.6	39	9
DOUBLE FENCE DAM	798.87	.9	45	15

$COST OF DAMS, $COST OF PROTOTYPE HEADCUT CONTROL AND $VALUE OF SEDIMENT

	LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
PER CU YD	30.00	32.10	38.40	44.10		
PER DAM	892.00	954.44	700.84	624.05	.00	1097.62
3 DAMS	2675.99	2863.31	2102.52	1872.16		3292.85

```
TABLE OF SPACING VS SPILLWAY  HEIGHT
     SPLWY HGHT      SPACING

          1.0           83.40
          1.5          125.10
          2.0          166.80
          2.5          208.50
          3.0          250.20
          3.5          291.90
          4.0          333.60

ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS


ENTER PLOT ENABLE CODE
          0 - NO PLOT DESIRED
          1 - PLOT DESIRED

ENTER 5 CURVE PLOT CODES IN THIS ORDER
          LOOSE ROCK DAM
          WIREBOUND LOOSE ROCK DAM
          SINGLE FENCE DAM
          DOUBLE FENCE DAM
          SEDIMENT VALUE

          0-NO PLOT DESIRED
          1 - PLOT DESIRED

ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
```

```
DATE IS 051381      PHASE1
HYPOTHETICAL RESTORATION PROJECT:  PHASE 1 - DESIGN ALTERNATIVES


GULLY =     1
REACH =     3  OF     3
GRADIENT    =    6.00 %
PEAK FLOW   =   50.00 CFS


KEYS ARE 2 FT
ROCKS ARE ANGLR
HEADCUT YES
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
ENTER LENGTH OF REACH,TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT


SPACING=  180.83 FT     DAM HEIGHT =    5.50 FT
NO. OF DAMS =    3.32      NDAMS =    3

DAM DIMENSIONS
     DAM HEIGHT                    =    5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT               =    3.25 FT
     TOP LENGTH OF SPILLWAY        =    7.17 FT
     EFFECTIVE LENGTH OF SPILLWAY =    4.94 FT
     BOTTOM LENGTH OF SPILLWAY     =    2.70 FT
     DEPTH OF SPILLWAY             =    2.25 FT

MATERIALS AND COSTS          LOOSE ROCK DAM
     ROCK VOLUME =   19.39 CU YD     COST = $  581.73

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT     8.0 FT LENGTH EACH

MATERIALS AND COSTS          WIREBOUND LOOSE ROCK DAM
     ROCK VOLUME =   19.39 CU YD     COST = $  622.45
     WIRE FOR DAM
     LENGTH OF MESH  =    9.58 FT
     WIDTH OF MESH  =   41.36 FT
     TOTAL MESH     =  396.32 SQ FT

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT     8.0 FT LENGTH EACH

MATERIALS AND COSTS          SINGLE FENCE DAM
```

```
     ROCK VOLUME =   12.72 CU YD     COST = $[illegible]8.34

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =    9.58 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =   52.71 SQ FT
        2 POSTS AT      8.0 FT LENGTH EACH
        2 POSTS AT      5.5 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH

MATERIALS AND COSTS          DOUBLE FENCE DAM
     ROCK VOLUME =   10.34 CU YD     COST = $  455.96

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   19.17 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.42 SQ FT
        4 POSTS AT      8.0 FT LENGTH EACH
        4 POSTS AT      5.5 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH


$COST PER DOUBLE FENCE DAM GT $COST PER HEADCUT CONTROL
USE PROTOTYPE HEADCUT CONTROL
```

TOTAL ROCK VOLUME FOR 3 DAMS,ONE HEADCUT CONTROL, AND TOTAL SEDIMENT CATCH IN CU YD.

LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
58.17	58.17	38.15	31.02	12.50	207.02

WIRE MESH AND POSTS PER TREATMENT (1 ROLL=2.7FT BY 330FT)

TYPE OF DAM	WIRE MESH AREA SQ FT	WIRE MESH NUMBER OF ROLLS	NUMBER POSTS AT 8.00 FT	NUMBER POSTS AT 5.50 FT
LOOSE ROCK DAM	317.62	.4	30	0
WIREBOUND LOOSE ROCK DAM	1506.59	1.7	30	0
SINGLE FENCE DAM	475.75	.5	36	6
DOUBLE FENCE DAM	633.87	.7	42	12

$COST OF DAMS,$COST OF PROTOTYPE HEADCUT CONTROL AND $VALUE OF SEDIMENT

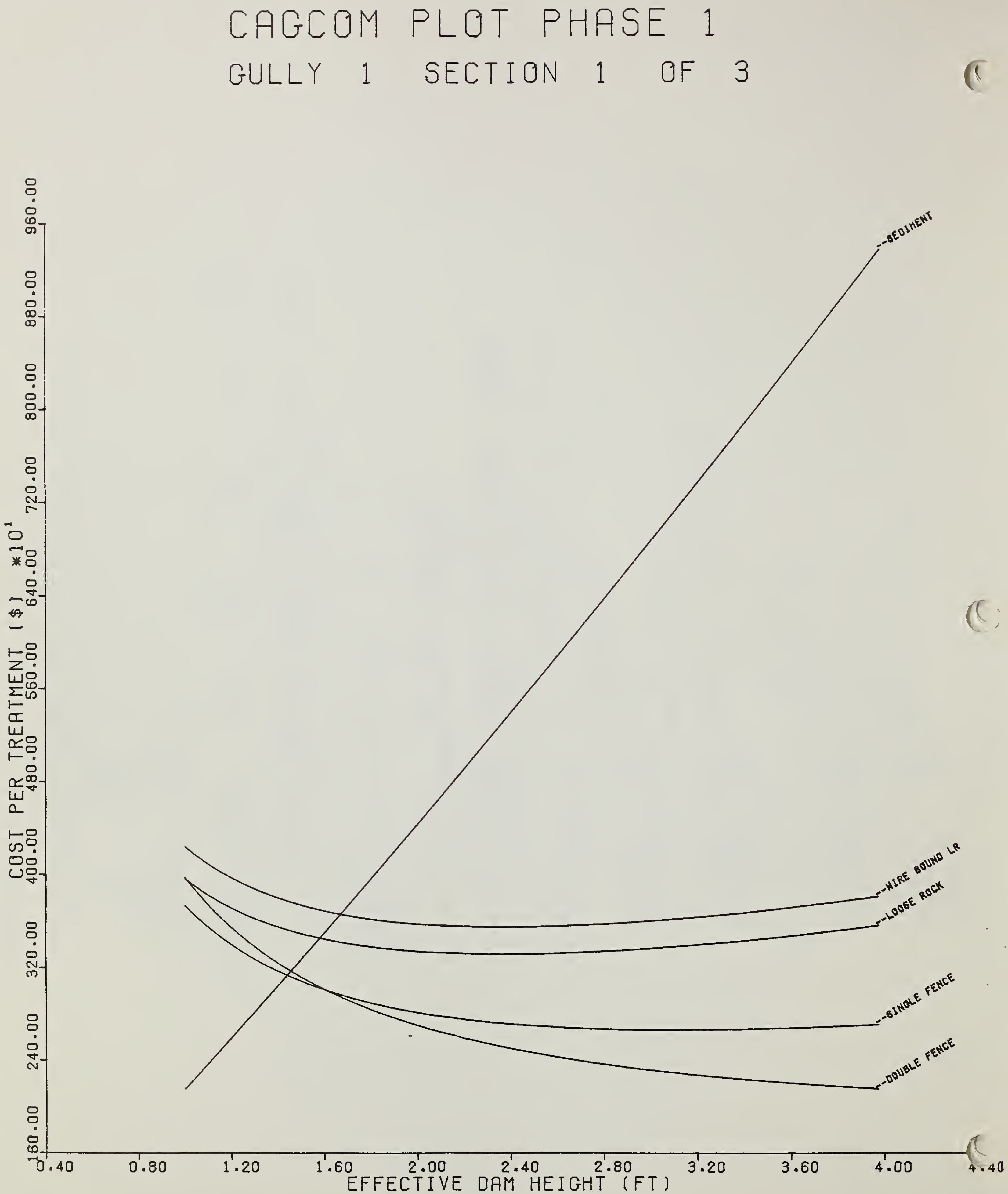
	LOOSE ROCK	WIREBOUND LOOSE ROCK	SINGLE FENCE	DOUBLE FENCE	HEADCUT	SEDIMENT
PER CU YD	30.00	32.10	38.40	44.10		
PER DAM	581.73	622.45	488.34	455.96	375.00	345.03
3 DAMS	1745.19	1867.35	1465.03	1367.87		1035.08

TABLE OF SPACING VS SPILLWAY HEIGHT

SPLWY HGHT	SPACING
1.0	55.66
1.5	83.48
2.0	111.31
2.5	139.14
3.0	166.97
3.5	194.79

```
ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS

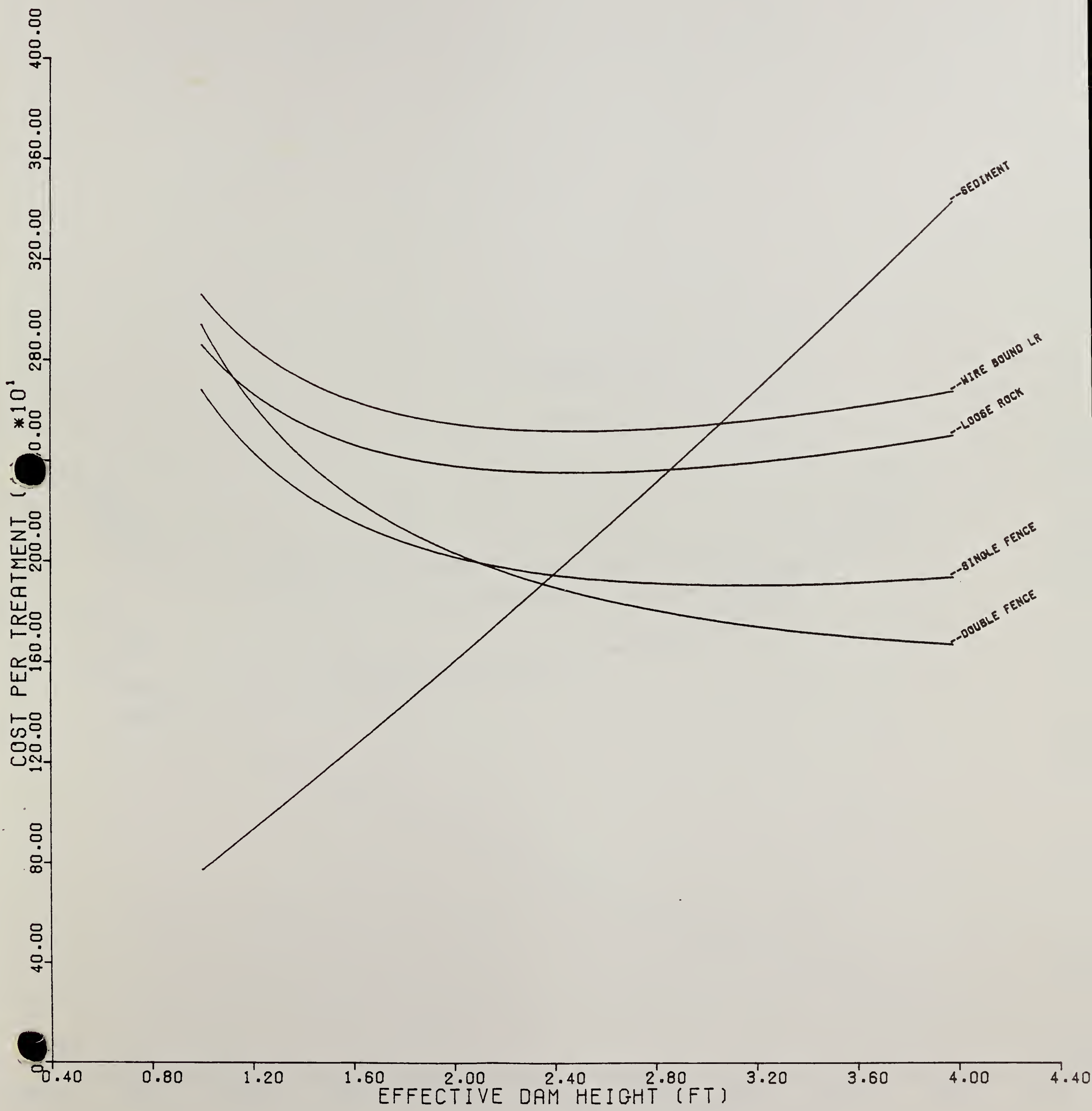

END OF INPUT FILE REACHED.
SECTION ID IS      0     0     0
```



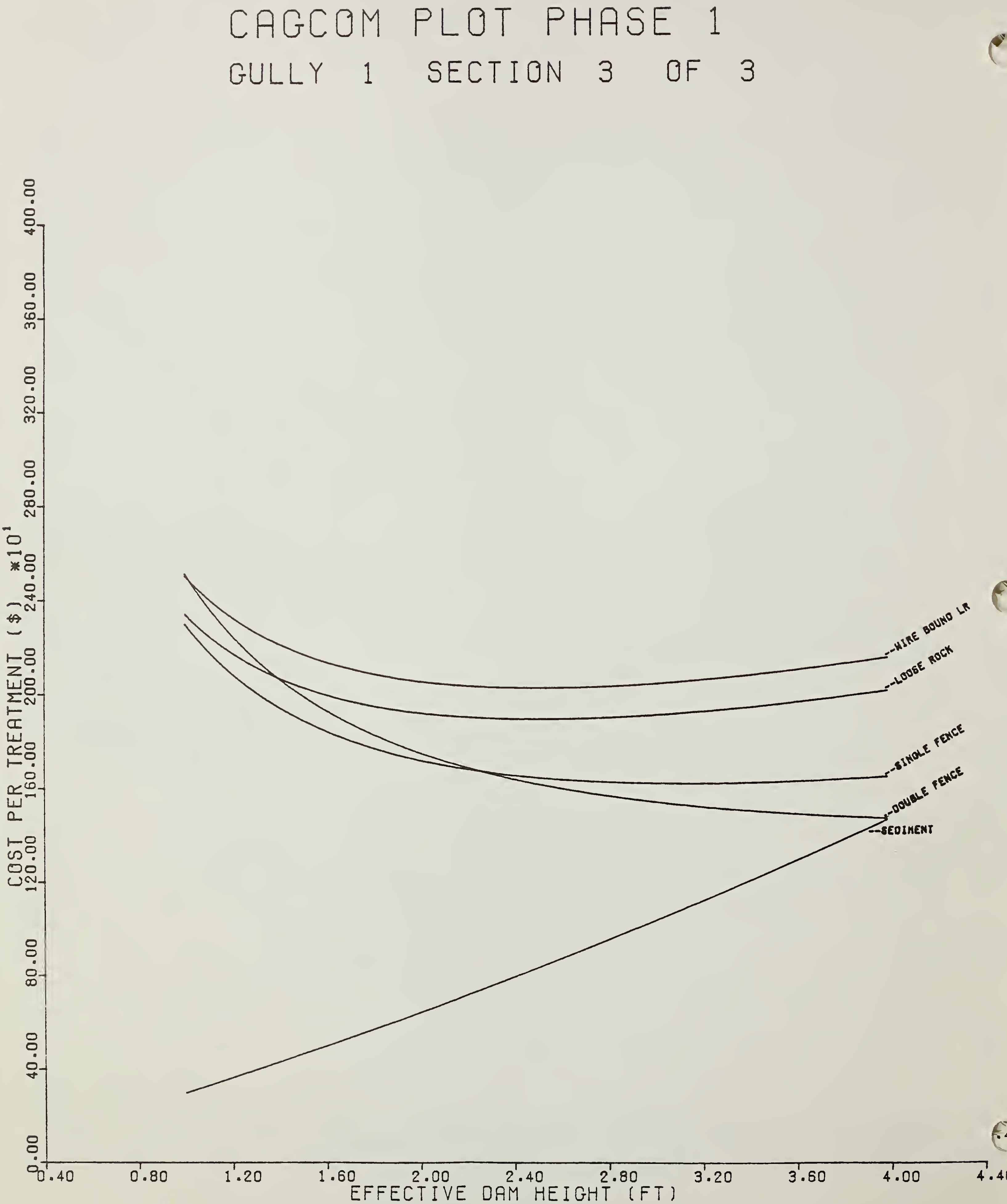
EXAMPLE PLOT FOR CAGCOM

CAGCOM PLOT PHASE 1

GULLY 1 SECTION 2 OF 3



EXAMPLE PLOT FOR CAGCOM



EXAMPLE PLOT FOR CAGCOM

Appendix IV

Phase II

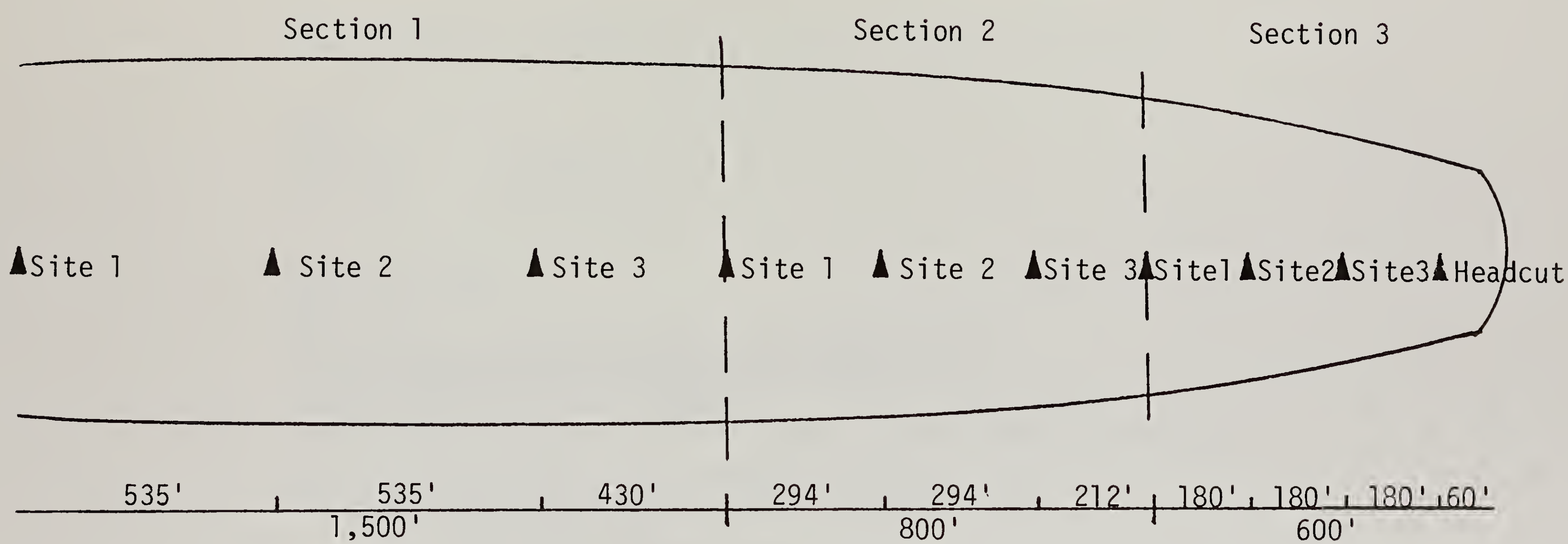
The following is an example of the required input and the resulting output for the execution of Phase II of the CAGCOM program. 1/ Refer to the accompanying figures for gully specifications and dimensions of the specific sites. As in the example for Phase I, cost of the rock and value of the sediment were taken as $30.00 per cubic yard and $5.00 per cubic yard, respectively.

<u>Example of Input for Phase II</u> 2/

```
WSDU*SAM(1).CAGCOM-2
2
HYPOTHETICAL RESTORATION PROJECT:  PHASE 2 - SPECIFIC DAM SITES
1,30,5.00
1,1,3
2,100,4,0,0
3.2,535
1,4,20,15,5,1
2,4,18,12,5,4
3,4,16,8,5,4
-1,1,2,3,4,5
1,2,3
4,75,2,1,0
3.5,294
1,3,15,10,6,5
2,3,12,9,6,5
3,3,11,7,6,5
-1,1,2,3,4,5
1,3,3
6,50,2,1,1
3.3,180
1,2,10,5,6,5
2,1,8,4,5,4
3,1,8,3,5,4
4,5,6,3,5,3
-1,1,2,3,4,5
0,0,0
```

1/ The example was developed by John P. Potyondy, Hydrologist, Region 4.

2/ For explicit execution instructions refer to WSDG's USERGUIDE program.



	Section 1			Section 2			Section 3			
Effective dam height from Phase 1	3.2 ft			3.5 ft			3.3 ft			
Spacing from Phase 1	535 ft			294 ft			180 ft			
NDAMS from Phase 1	3			3			3			
Site	1	2	3	1	2	3	1	2	3	4
Structure type	Double fence	Double fence	Double fence	Single fence	Single fence	Single fence	WBLR	WB	WB	HC
Gully top width (ft)	20	18	16	15	12	11	10	8	8	6
Gully bottom width (ft)	15	12	8	10	9	7	5	4	3	3
Gully depth (ft)	5	5	5	6	6	6	6	5	5	5
Effective dam height (ft)	1	4	4	5	5	5	5	4	4	3

Gully specifications for example problem--Phase 2.

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789(12345

@ASG,A WSDU*WATER.
FACILITY WARNING  000200000000

@ASG,A WSDU*SAM.
FACILITY WARNING  000200000000

@XQT WSDU*WATER.CAGCOM
   ENTER 1 TO RUN PHASE1 OR 2 TO RUN PHASE2

@ADD,P WSDU*SAM.CAGCOM-2

 ENTER 72 CHARACTERS OF IDENTIFYING INFORMATION FOR THIS RUN

 ENTER DAM TYPE, DAM'S BASE COST, UNIT VALUE OF SEDIMENT
 USE THE FOLLOWING NUMERIC CODES TO ENTER DAM TYPE.
      1 = LOOSE ROCK (LR)
      2 = WIREBOUND LOOSE ROCK (WB)
      3 = SINGLE FENCE (SF)
      4 = DOUBLE FENCE (DF)

 ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS

 ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
```

```
DATE IS 051381      PHASE2
HYPOTHETICAL RESTORATION PROJECT:  PHASE 2 - SPECIFIC DAM SITES


GULLY =      1
REACH =      1   OF      3
GRADIENT    =      2.00 %
PEAK FLOW    =   100.00 CFS


KEYS ARE 4 FT
ROCKS ARE ROUND
HEADCUT NO
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
 ENTER EFFECTIVE DAM HEIGHT(FT) AND SPACING(FT)
BETWEEN DAMS FROM PHASE 1 OUTPUT


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT




***********
SITE NUMBER    1.      DOUBLE FENCE DAM
GULLY DIMENSIONS
     TOP WIDTH     =    20.00 FT
     BOTTOM WIDTH =    15.00 FT
     DEPTH         =     5.00 FT


SINCE GULLY DEPTH IS BETWEEN 2.5 AND 5, ALTERNATE SPILLWAY CALCULATION USED.

DAM DIMENSIONS
     DAM HEIGHT                     =     4.54 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                =     1.00 FT
     TOP LENGTH OF SPILLWAY         =     9.00 FT
     EFFECTIVE LENGTH OF SPILLWAY =     5.00 FT
     BOTTOM LENGTH OF SPILLWAY     =     1.00 FT
     DEPTH OF SPILLWAY             =     3.54 FT

SEDIMENT
          VOLUME =    47.84 CU YD      VALUE = $  239.20

MATERIALS AND COSTS
     ROCK VOLUME =    17.01 CU YD      COST  = $  750.24

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =    39.08 FT
     WIDTH OF MESH  =     4.54 FT
     TOTAL MESH      =   177.53 SQ FT
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      6 POSTS AT      7.5 FT LENGTH EACH
      6 POSTS AT      5.0 FT LENGTH EACH

    WIRE AND POSTS FOR BANK PROTECTION
    LENGTH OF MESH =   15.90 FT
    WIDTH OF MESH  =    4.54 FT
    TOTAL MESH     =   72.21 SQ FT
      8 POSTS AT      7.5 FT LENGTH EACH


ENTER NEXT SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT




***********
SITE NUMBER    1.5     DOUBLE FENCE DAM           AUXILIARY DAM SITE
LOCATION IS  166.70 FT UPSTREAM FROM DAM SITE   1.0
GULLY DIMENSIONS
    TOP WIDTH    =   19.00 FT
    BOTTOM WIDTH =   13.50 FT
    DEPTH        =    5.00 FT


SINCE GULLY DEPTH IS BETWEEN 2.5 AND 5, ALTERNATE SPILLWAY CALCULATION USED.

DEPOSITS EXTEND   368.30 FT UPSTREAM FROM DAM NUMBER     1.5

DAM DIMENSIONS
    DAM HEIGHT                   =    4.94 FT
    SPILLWAY HEIGHT              =    2.21 FT
    TOP LENGTH OF SPILLWAY       =   10.12 FT
    EFFECTIVE LENGTH OF SPILLWAY =    7.40 FT
    BOTTOM LENGTH OF SPILLWAY    =    4.67 FT
    DEPTH OF SPILLWAY            =    2.73 FT

SEDIMENT
        VOLUME =  221.69 CU YD     VALUE = $ 1108.46

MATERIALS AND COSTS
    ROCK VOLUME =   17.36 CU YD     COST  = $  765.71

    WIRE AND POSTS FOR DAM
    LENGTH OF MESH =   37.86 FT
    WIDTH OF MESH  =    4.94 FT
    TOTAL MESH     =  186.97 SQ FT
      6 POSTS AT      7.5 FT LENGTH EACH
      6 POSTS AT      5.0 FT LENGTH EACH

    WIRE AND POSTS FOR BANK PROTECTION
    LENGTH OF MESH =   17.28 FT
    WIDTH OF MESH  =    4.94 FT
    TOTAL MESH     =   85.34 SQ FT
     10 POSTS AT      7.5 FT LENGTH EACH
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***********
SITE NUMBER   2.     DOUBLE FENCE DAM
GULLY DIMENSIONS
      TOP WIDTH     =   18.00 FT
      BOTTOM WIDTH =   12.00 FT
      DEPTH         =    5.00 FT


SINCE GULLY DEPTH IS BETWEEN 2.5 AND 5, ALTERNATE SPILLWAY CALCULATION USED.

DAM DIMENSIONS
      DAM HEIGHT                    =     5.00 FT
      THE SPILLWAY HEIGHT VALUE WAS CHANGED.
      SPILLWAY HEIGHT               =     3.05 FT
      TOP LENGTH OF SPILLWAY        =    14.06 FT
      EFFECTIVE LENGTH OF SPILLWAY =    12.23 FT
      BOTTOM LENGTH OF SPILLWAY     =    10.39 FT
      DEPTH OF SPILLWAY             =     1.95 FT

SEDIMENT
            VOLUME =  396.65 CU YD      VALUE = $ 1983.23

MATERIALS AND COSTS
      ROCK VOLUME =   16.27 CU YD      COST  = $  717.49

      WIRE AND POSTS FOR DAM
      LENGTH OF MESH =   36.00 FT
      WIDTH OF MESH  =    5.00 FT
      TOTAL MESH     =  180.00 SQ FT
         6 POSTS AT      7.5 FT LENGTH EACH
         6 POSTS AT      5.0 FT LENGTH EACH

      WIRE AND POSTS FOR BANK PROTECTION
      LENGTH OF MESH =   17.50 FT
      WIDTH OF MESH  =    5.00 FT
      TOTAL MESH     =   87.50 SQ FT
        10 POSTS AT      7.5 FT LENGTH EACH


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT



***********
SITE NUMBER   3.     DOUBLE FENCE DAM
GULLY DIMENSIONS
      TOP WIDTH     =   16.00 FT
      BOTTOM WIDTH =    8.00 FT
      DEPTH         =    5.00 FT

SINCE GULLY DEPTH IS BETWEEN 2.5 AND 5, ALTERNATE SPILLWAY CALCULATION USED.
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DAM DIMENSIONS
     DAM HEIGHT                        =     5.00 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                   =     2.85 FT
     TOP LENGTH OF SPILLWAY            =    12.60 FT
     EFFECTIVE LENGTH OF SPILLWAY =    10.60 FT
     BOTTOM LENGTH OF SPILLWAY         =     8.61 FT
     DEPTH OF SPILLWAY                 =     2.15 FT

SEDIMENT
          VOLUME =  258.53 CU YD      VALUE = $ 1292.66

MATERIALS AND COSTS
     ROCK VOLUME =   13.68 CU YD      COST  = $  603.50

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   32.00 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =  160.00 SQ FT
        5 POSTS AT      7.5 FT LENGTH EACH
        5 POSTS AT      5.0 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   17.50 FT
     WIDTH OF MESH  =    5.00 FT
     TOTAL MESH     =   87.50 SQ FT
       10 POSTS AT      7.5 FT LENGTH EACH


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT


***TOTALS FOR SECTION***


NUMBER OF DAM SITES IS
NO HEADCUT CONTROL THIS SECTION.

TOTAL ROCK VOLUME IS        64.33 CU YD
TOTAL SEDIMENT CATCH IS    924.71 CU YD


WIRE MESH AND POSTS PER TREATMENT (1 ROLL=2.7FT BY 330FT)
TOTAL AREA WIRE MESH IS      1037.05 SQ FT
TOTAL NUMBER ROLLS OF WIRE      1.2  ROLLS
NUMBER POSTS AT  5.0 FT IS   23.
NUMBER POSTS AT  7.5 FT IS   61.

TOTAL COST IS            $  2836.34
TOTAL SEDIMENT VALUE IS $  4623.55

ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS


ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
```

```
DATE IS 051381      PHASE2
HYPOTHETICAL RESTORATION PROJECT:  PHASE 2 - SPECIFIC DAM SITES


GULLY =     1
REACH =     2   OF      3
GRADIENT   =      4.00 %
PEAK FLOW   =    75.00 CFS


KEYS ARE 2 FT
ROCKS ARE ANGLR
HEADCUT NO
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
 ENTER EFFECTIVE DAM HEIGHT(FT) AND SPACING(FT)
BETWEEN DAMS FROM PHASE 1 OUTPUT


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT




***********
SITE NUMBER   1.      SINGLE FENCE DAM
GULLY DIMENSIONS
     TOP WIDTH     =   15.00 FT
     BOTTOM WIDTH =   10.00 FT
     DEPTH         =    6.00 FT

DAM DIMENSIONS
     DAM HEIGHT                    =     5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT               =     3.52 FT
     TOP LENGTH OF SPILLWAY        =    10.83 FT
     EFFECTIVE LENGTH OF SPILLWAY =     8.99 FT
     BOTTOM LENGTH OF SPILLWAY     =     7.14 FT
     DEPTH OF SPILLWAY             =     1.98 FT

SEDIMENT
          VOLUME =  219.52 CU YD     VALUE = $ 1097.62

MATERIALS AND COSTS
     ROCK VOLUME =   18.25 CU YD     COST   = $   700.84

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   14.58 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =   80.21 SQ FT
        3 POSTS AT     8.0 FT LENGTH EACH
        3 POSTS AT     5.5 FT LENGTH EACH
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```
     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT



***********
SITE NUMBER   2.     SINGLE FENCE DAM
GULLY DIMENSIONS
     TOP WIDTH    =   12.00 FT
     BOTTOM WIDTH =    9.00 FT
     DEPTH        =    6.00 FT

DAM DIMENSIONS
     DAM HEIGHT                      =    5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                 =    3.17 FT
     TOP LENGTH OF SPILLWAY          =    9.00 FT
     EFFECTIVE LENGTH OF SPILLWAY =    7.02 FT
     BOTTOM LENGTH OF SPILLWAY       =    5.05 FT
     DEPTH OF SPILLWAY               =    2.33 FT

SEDIMENT
          VOLUME =  151.74 CU YD     VALUE = $  758.70

MATERIALS AND COSTS
     ROCK VOLUME =   16.25 CU YD     COST  = $  624.00

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   11.75 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =   64.62 SQ FT
        2 POSTS AT      8.0 FT LENGTH EACH
        2 POSTS AT      5.5 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT      8.0 FT LENGTH EACH


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT



***********
SITE NUMBER   3.     SINGLE FENCE DAM
```

```
GULLY DIMENSIONS
     TOP WIDTH     =   11.00 FT
     BOTTOM WIDTH =     7.00 FT
     DEPTH         =    6.00 FT

DAM DIMENSIONS
     DAM HEIGHT                      =    5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                 =    2.84 FT
     TOP LENGTH OF SPILLWAY          =    8.08 FT
     EFFECTIVE LENGTH OF SPILLWAY =    5.75 FT
     BOTTOM LENGTH OF SPILLWAY       =    3.41 FT
     DEPTH OF SPILLWAY               =    2.66 FT

SEDIMENT
          VOLUME =   98.55 CU YD     VALUE = $  492.76

MATERIALS AND COSTS
     ROCK VOLUME =   14.27 CU YD     COST  = $  547.98

     WIRE AND POSTS FOR DAM
     LENGTH OF MESH =   10.67 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =   58.67 SQ FT
        2 POSTS AT     8.0 FT LENGTH EACH
        2 POSTS AT     5.5 FT LENGTH EACH

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =    5.50 FT
     TOTAL MESH     =  105.87 SQ FT
       10 POSTS AT     8.0 FT LENGTH EACH


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT


***TOTALS FOR SECTION***


NUMBER OF DAM SITES IS   3
NO HEADCUT CONTROL THIS SECTION.

TOTAL ROCK VOLUME IS        48.77 CU YD
TOTAL SEDIMENT CATCH IS   469.82 CU YD


WIRE MESH AND POSTS PER TREATMENT (1 ROLL=2.7FT BY 330FT)
TOTAL AREA WIRE MESH IS       521.12 SQ FT
TOTAL NUMBER ROLLS OF WIRE       .6  ROLLS
NUMBER POSTS AT  5.5 FT IS    7.
NUMBER POSTS AT  8.0 FT IS   37.

TOTAL COST IS             $  1872.92
TOTAL SEDIMENT VALUE IS $  2349.08
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ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS

ENTER GRADIENT,PEAK FLOW,KEY,ROCK,HEADCUT
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```
DATE IS 051381      PHASE2
HYPOTHETICAL RESTORATION PROJECT:  PHASE 2 - SPECIFIC DAM SITES


GULLY =     1
REACH =     3  OF     3
GRADIENT   =     6.00 %
PEAK FLOW   =   50.00 CFS


KEYS ARE 2 FT
ROCKS ARE ANGLR
HEADCUT YES
BASE COST IS  $ 30.00 PER CU YD FOR LOOSE ROCK DAM
       UNIT VALUE IS $  5.00 PER CU YD OF SEDIMENT
 ENTER EFFECTIVE DAM HEIGHT(FT) AND SPACING(FT)
BETWEEN DAMS FROM PHASE 1 OUTPUT


ENTER SITE, STRUCTURE TYPE, TOP WIDTH OF GULLY,
BOTTOM WIDTH OF GULLY, DEPTH OF GULLY, SPILLWAY HEIGHT



***********
SITE NUMBER   1.     WIREBOUND LOOSE ROCK DAM
GULLY DIMENSIONS
     TOP WIDTH     =   10.00 FT
     BOTTOM WIDTH =    5.00 FT
     DEPTH         =    6.00 FT

DAM DIMENSIONS
     DAM HEIGHT                     =     5.50 FT
     THE SPILLWAY HEIGHT VALUE WAS CHANGED.
     SPILLWAY HEIGHT                =     3.25 FT
     TOP LENGTH OF SPILLWAY         =     7.17 FT
     EFFECTIVE LENGTH OF SPILLWAY =     4.94 FT
     BOTTOM LENGTH OF SPILLWAY      =     2.70 FT
     DEPTH OF SPILLWAY              =     2.25 FT

SEDIMENT
          VOLUME =   69.01 CU YD     VALUE = $  345.03

MATERIALS AND COSTS
     ROCK VOLUME =   19.39 CU YD     COST  = $  622.45
     WIRE FOR DAM
     LENGTH OF MESH =     9.58 FT
     WIDTH OF MESH  =    41.36 FT
     TOTAL MESH     =  396.32 SQ FT

     WIRE AND POSTS FOR BANK PROTECTION
     LENGTH OF MESH =   19.25 FT
     WIDTH OF MESH  =     5.50 FT
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NUMBER POSTS AT  7.5 FT IS    20.
NUMBER POSTS AT  8.0 FT IS    10.

TOTAL COST IS            $  1587.35
TOTAL SEDIMENT VALUE IS $    708.24

ENTER   GULLY NUMBER,  SECTION NUMBER,  TOTAL NUMBER OF SECTIONS


 END OF INPUT FILE REACHED.
 SECTION ID IS      0     0     0
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